

Point-of-care critical ultrasound in a rural emergency department

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Abstract

Point-of-care critical ultrasound (CCUS) has changed the management of critically ill patients in the emergency department. It is brought to the bed of patient, images are immediately available and therapy can be monitored making real time changes. Although it is difficult to estimate the real efficacy of CCUS, we evaluated the impact of ultrasound in our emergency department. This study is a cross sectional observational study with 241 cases enrolled. All patients were evaluated by the emergency physician and underwent clinical examination and then CCUS. Patients were then independently evaluated by at least one consultant. A final diagnosis was made after an agreement between the emergency physician and the consultant. Percentages of correct final diagnosis were higher after CCUS than after primary survey: 82.5% *vs* 49.1% of patients with dyspnea ($P < 0.001$), 71.9% *vs* 40.6% with thoracic pain ($P = 0.03$), 76.2% *vs* 45% with abdominal pain ($P < 0.001$), 80.0% *vs* 43.6% with suspected deep venous thrombosis ($P = 0.03$) and 80.0% *vs* 20% with shock ($P = 0.014$). Extended fast assessment for trauma was effective for the management of traumatic patients and correctly ruled out complications in 81.1% of patients ($P = 0.04$). A small number of ultrasound guided invasive procedures were safely and successfully performed. In our study the integration of primary survey with CCUS increased diagnostic capability of the emergency physician and improved overall quality of medical assistance.

Introduction

Point-of-care critical ultrasound (CCUS) improves diagnostic capabilities, reduces complications of invasive procedures and is effective in the management of critically ill patients.¹ CCUS's portability, feasibility and cost effectiveness have determined a worldwide diffusion of the technique. Ultrasound (US) technology was integrated in the emergency department (ED) in the last decades to

help the rapid identification of the etiology of diseases and to integrate physical examination, which is often not reliable enough.^{2,3}

Point-of-care critical ultrasound is brought to the bed of patients, images are immediately available and interpreted according with clinical symptoms and signs. It can be either multi-organ in more complex and critical conditions (cardiac arrest, unknown hypotension, shock)⁴⁻⁶ or focal, limited, goal-directed to answer just one or few clinical questions (deep venous thrombosis, renal colic, pneumothorax).¹ The emergency physician (EP) can also monitor the effectiveness of medical therapy making real time changes of diagnostic and therapeutic procedures.^{7,8}

Point-of-care critical ultrasound has broken some old and untouchable barriers, like those represented by lungs [lung ultrasound (LUS)];⁸ critical care echocardiography (CCEC) has been introduced in critical care area and it is now a useful instrument for the EP;⁹ fast assessment for trauma (FAST), followed by the extended FAST to lung injuries (EFAST), is worldwide considered as a valid protocol for the management of trauma;^{10,11} CCUS is successfully used in some remote settings, like rural and desert areas, in the space and in war scenarios.^{12,13}

For the same reason, CCUS has been introduced in pre-hospital settings, in the ambulance and in small hospitals where diagnostic tools are limited and where the radiologist and the majority of specialists are not available 24 hours a day.

Although it is difficult to estimate the real impact of CCUS in these settings, aim of the study was to evaluate the role of CCUS on diagnostic and therapeutic procedures in our emergency department. We compared diagnosis made after primary survey, after ultrasound and by a specialist and we evaluated the percentages of cases in which CCUS had been decisive in obtaining a definite diagnosis.

Materials and Methods

We planned an observational study and we enrolled 241 consecutively clinical cases from July 2013 until December 2013 in the emergency departments of Cazzavillan Hospital in Arzignano (VI), Italy. It is a medium size emergency department with a mean of 35,000 accesses per year.

Patients were screened during the daily shifts (from 8 to 20 o'clock) when all the consultants and radiologists are usually available in our hospital. Cases were consecutively sampled whenever one of the designated ultrasound operators were on duty.

Criteria for enrollment included the presence of one of the following syndrome and are

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summarized in Table 1: shock or cardiac arrest, dyspnea, non traumatic chest pain, abdominal pain, trauma involving chest and/or abdomen, a suspected diagnosis of deep venous thrombosis.

Firstly all patients underwent primary survey (PS) during which physicians collected information about patient's history, signs, symptoms and physical examination. Electrocardiography and a point-of-care blood hemogasanalysis were also immediately available during PS.

Point-of-care critical ultrasound was then performed by the same emergency physician. Further examinations (both laboratory and radiological) were prescribed when necessary and at least one independent consultant evaluation was collected.

The emergency physician filled in an electronic worksheet where he reported the following steps: supposed diagnosis after primary survey, CCUS performed, supposed diagnosis after CCUS, other diagnostic procedures performed, a comment upon the role of CCUS.

Discharge diagnosis was the reference point and it was made after the examination of clinical, laboratory and radiological documentations of every patient by the EP together with the consultant. Cases without agreement were classified as *not determined*.

Ultrasound examinations were grouped into 6 categories: 1- LUS; 2- CCEC; 3- Abdominal US (AUS); 4- Multiorgan Ultrasound (MU); 5. EFAST; 6- CUS (compression ultrasonography). Number and type of invasive procedures were also registered. We compared diagnosis made after each step (after PS, after CCUS and definitive diagnosis) and the improvement of diagnostic capability obtained by the application of CCUS was evaluated. For traumatic patients the main goal was the detection of a major complications of trauma: pneumothorax, lung contusion, pleural and pericardial effusion, haemoperitoneum. Emergency physicians were also asked to comment upon the role of CCUS after every case according to the following classification: crucial for diagnosis, supported the clinical data, simply ruled out a suspected diagnosis, misleading. Primary endpoint was the estimation of the improvement of diagnostic capability obtained by CCUS comparing the diagnosis made after PS and CCUS with discharge diagnosis. Secondary endpoints was the evaluation of the feasibility of CCUS in all the different clinical situations faced in the emergency department and the assessment of the appreciation perceived by the emergency physicians.

The study was approved by local committee. Informed consent was collected, even if it was not possible to obtain it from critically ill and unconscious subjects or affected by cardiac arrest.

Point-of-care critical ultrasound technique

Point-of-care critical ultrasound was always performed after PS. Focused assessments were used for localized and well defined symptoms [renal colic, cholecystitis, pneumothorax, deep vein thrombophlebitis (DVT)], while a multi-organ approach was chosen in complex syndromes or in critically ill patients. We applied some specific protocols: EFAST in trauma, CUS

for deep venous thrombosis, Rapid Ultrasound in SHock (RUSH) and multiorgan ultrasonographic (MU) approach in patients with shock, cardiac arrest, unknown hypotension.¹⁴ CUS was integrated with the dosage of D-dimer for those patients with normal ultrasound findings but with a high preclinical Wells score (data not shown). If D-dimer had been higher than normal, patients would have been instructed to perform a doppler ultrasound within 10 days, while patients with normal D-dimer test would have safely discharged without any anticoagulant therapy.^{15,16}

Some invasive procedures were also guided by US: central venous catheterization, thoracentesis, paracentesis, abscess drainage. All scans were performed in two dimensional grey scale with the patient in a supine upright position using an Esaote Mylab 30 with a curvilinear probe (2-5 MHz) for LUS, AUS, EFAST and multiorgan ultrasound, a sector probe (2-3 MHz) for CCEC and a linear 7-12 MHz probe for CUS, LUS and to guide invasive procedures. Operators were certified emergency physicians who had accomplished the competency training program for *UltraSound Life Support* (Basic Management/Level 1 - Provider) provided by Winfocus.

Statistical analysis

We expressed as percentages admission symptoms, type of US performed, correct and incorrect diagnosis made after PS and CCUS and the role of CCUS. Diagnosis made after PS and after CCUS were then expressed as correct and incorrect with respect to definitive diagnosis and differences were calculated using chi-square analysis. Fisher's exact test was used for the analysis of smaller groups. Invasive procedures were excluded from statistical analysis and the number of failures and side effects were only reported. Results were considered statistically significant for P value lower than 0.05. Statistical analysis was made using SPSS 16.0.

Results

Five hundred and seventy-four patients had been initially evaluated for the study and 241 were finally recruited: 113 women (47.2%; mean age 55.35±22.77, minimum 12, maximum 99 years old) and 128 men (52.8%; mean age 56.33±21.61; minimum 14, maximum 94 years old). The majority of patients were excluded at the time of data analysis for incomplete documentation, wrong triage diagnostic evaluation and lack of consultant evaluation. Percentages of symptoms and ultrasounds are described respectively in Table 1 and in Figure 1.

After PS a true positive diagnosis was made in 49.1% of subjects with dyspnea, 40.6% of patients with chest pain, 45.0% of patients with abdominal pain, 40.0% of patients with suspected deep venous thrombosis and 20% of shocks.

Diagnostic capability significantly increased after CCUS, which fulfilled largely our primary endpoint (Figure 2). A final clinical diagnosis was achieved in 82.5% of patients with dyspnea (+33.4% in comparison with PS alone) (P<0.001), 71.9% of patients with chest pain (+31.3%) (P=0.03), in 76.2% of patients with abdominal pain (+31.2%) (P<0.001), in 80.0% of patients with suspected deep venous thrombosis (+36.4%) (P=0.03) and in 80% of shocks (+60%) (P=0.014).

We did not register any new deep venous thrombosis in those patients with a high pre-clinical Wells score and a high D-Dimer who performed a second examination within 10 days from the previous one.

In traumatic patients emergency physicians suspected a complication of trauma in 32.4% of cases after PS. Instead, complications were correctly identified in 81.1% of cases by EFAST (+48.7%) (P=0.04).

We performed 18 invasive procedures: 7

Table 1. Summary of inclusion symptoms and percentages of patients recruited.

Syndrome	Symptoms	Patients (%)
Dyspnea	A-traumatic, acute* respiratory insufficiency (Oximetry<88%), shortness of breath, cough, fever with mild hypoxia (Oximetry<93%)	23.7
Chest pain	A-traumatic, acute*, well localized or irradiated, spontaneous, independent of movements, with/without tachycardia, nausea, cold sweat, feeling faint/tired	13.3
Abdominal pain	A-traumatic, acute*, well-localized or a-specific, cramp-like or steady and unrelenting, with or without fever, nausea, vomit and constipation	33.2
Trauma	Trauma involving thorax and/or abdomen	15.4
Suspect of DVT of lower limb	A-traumatic swelling and/or warm and reddened skin and/or spontaneous pain and/or venous cord	12.4
Shock or cardiac arrest	Cardiac arrest, shock with or without unconsciousness, unknown hypotension	2.1

DVT, deep vein thrombophlebitis. *Acute onset, <24 h.

jugular vein catheterization, 1 femoral vein catheterization, 4 thoracentesis, 3 paracentesis, 2 arthrocentesis and 1 abdominal abscess drainage. One jugular vein catheterization failed in a patient affected by hypovolemic shock while we did not registered any complications. Finally 4.7% of cases were classified as undetermined.

Regarding our secondary endpoint, CCUS was performed in all cases faced in the study period of time. It never lasted more than 5 minutes, with some examinations that lasted less than 10 seconds (CCUS in cardiac arrest). According to the physicians' opinion, CCUS was crucial for the final diagnosis in 27.6% of cases, supported or confirmed clinical data in 56.1% of patients, ruled out specific clinical hypothesis without being decisive for the diagnosis in 14.2% of subject and was misleading in the remaining 2.1%, thus receiving much appreciation by all the operators. A schematic representation of the utility of CCUS is summarized in Table 2.

Misleading diagnosis was determined by a wrong interpretation of ultrasonographic images: a patient with a thoracic trauma suspected of having PNx after LUS and eventually affected by a large pulmonary bullae; a focal inferior hypokinesia of the left ventricle not confirmed by the cardiologist in a patient with nonspecific ST segment modifications and epigastric pain; one patient with jaundice and ultrasonographic evidence of gallbladder stones, but affected by chronic heart failure and congestive liver; a suspect of pulmonary embolism in a patient with right ventricle dilatation, chronic obstructive pulmonary disease and a final diagnosis of septic shock; a female with a fortuitous and not complicated peritoneal effusions in the pouch of Douglas.

The percentage of patients admitted to the hospital was 40.9%, 1.2% died (all cases were subjects with cardiac arrest), and the remaining 57.9% was discharged. Within each syndrome the percentages of admission and discharge were respectively 62.9% vs 37.1% for dyspnea, 37% vs 63% for thoracic pain, 32.4% vs 67.6% for trauma, 37.5% vs 62.5% for abdominal pain and 16% vs 84% for patients suspected of having DVT. All patients with shock or resuscitated were admitted to the hospital.

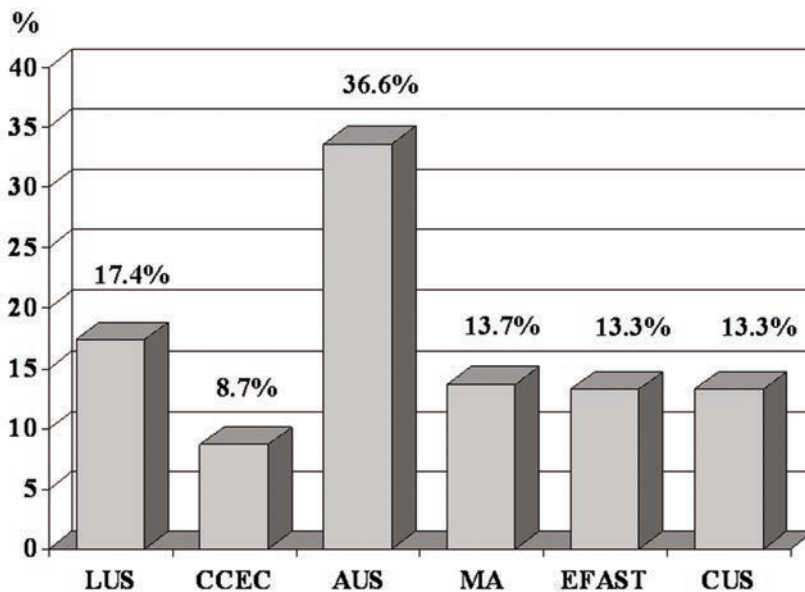


Figure 1. Percentages of ultrasounds performed.

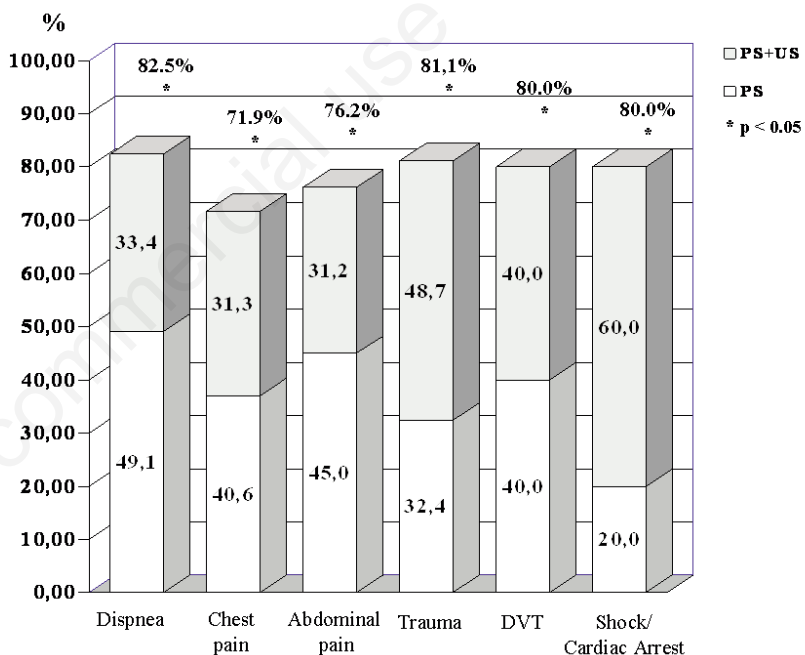


Figure 2. Percentages of correct final diagnosis registered after primary survey and primary survey + point-of-care critical ultrasound. The number of definitive diagnosis improved significantly after the use of ultrasound.

Table 2. A schematic representation of secondary endpoints.

Syndrome	CCUS crucial for the diagnosis (%)	CCUS supported clinical data (%)	Ruled out clinical hypothesis (%)	Misleading (%)
Dyspnea	22.8	68.4	8.8	0.0
Chest pain	53.1	18.8	21.9	6.2
Abdominal pain	58.8	27.5	11.2	2.5
Trauma	16.2	64.9	16.2	2.7
Suspect of DVT	60.0	20.0	20.0	0.0
Shock/cardiac arrest	42.9	28.6	14.3	14.3

CCUS, point-of-care critical ultrasound; DVT, deep vein thrombophlebitis. The role of point-of-care critical ultrasound is described for each syndrome according with physicians' judgement.

Discussion

Point-of-care critical ultrasound has dramatically changed the management of critically ill patients in the emergency department. Many papers have stressed the importance of CCUS in critical care area, but the majority of them are focused on specific topics or syndromes. In our work we tried to do something more, evaluating the role of CCUS in the daily clinical practice of a rural emergency departments, where different and concomitant syndrome are usually faced and where a radiologist and a consultant are not always available.

Firstly, we strongly stresses the importance of primary survey: ultrasound must integrate clinical assessment without replacing it. However, physical examination is not always possible or sufficient, for example in noisy environments, in not collaborating patients, in pre-hospital settings or in the ambulance. Moreover, physical examination is not reliable enough in mild syndromes and in those patients with many concurrent pathologies. For example, a mild heart failure is hardly diagnosed with the stethoscope and the X-ray will identify lung congestion if intrathoracic water exceeds the normal intrathoracic volume by 75%.¹⁴

Lung ultrasound is important for the management of dyspnea: B lines on pleural ultrasonography predict fluid overload, adding diagnostic accuracy to the physical examination and measurement of brain natriuretic peptide (Figure 3);¹⁷ pneumothorax and pleural effusions are rapidly and effectively diagnosed.⁷

In our study the percentage of correct diagnoses after lung ultrasound was extremely high and the emergency physicians were able to discriminate rapidly and effectively between a wet and a dry lung and to rule in or rule out pleural effusions or a pneumothorax. We also confirmed the feasibility of CUS for the management of patients with a suspect of deep venous thrombosis as shown by the high percentage of final correct diagnosis (Figure 3). According with other papers,¹⁸ our experience showed that learning curve of CUS had been extremely rapid for all the operators.

Patients with abdominal symptoms often required the examination of different organs, but functional bowel disorders of the intestine reduced diagnostic accuracy of ultrasound in several cases.

In our study the role of CCUS was often important even when it wasn't decisive for the diagnosis: for example the possibility to rule out life-threatening syndromes, like an abdominal aortic aneurysm in patients with intense abdominal pain, reduced concern and anxiety of operators (Figure 3B). As far as trauma is concerned, the majority of EFAST were performed to exclude complications of traumatic

injuries. Many studies have demonstrated that FAST reduces the need for CT and the time for an appropriate intervention, providing evidences of shorter hospital stay, lower costs and lower overall mortality.¹⁹ In our experience EFAST gave the indication to proceed directly to a CT scan or to surgery only in a minority of cases, but the possibility to rule out complications, such as hidden effusions, pneumothorax or lung contusions, was important for the management of trauma, safe-discharge, decision to transport or to not transport patients to the nearest trauma center.

The use of critical care echocardiography in the ED has also increased but it remains the most difficult technique. Although CCEC is

currently considered a crucial expertise for the emergency physician, this covers a limited differential diagnosis: to acquire standard transthoracic views in advanced life support maneuver, to identify major causes of cardiac arrest and shock, to recognize when a referral to a second opinion is indicated.⁹ In our analysis CCEC improved the management of chest pain and shock, but since heart diseases are complex, the assessment of a cardiologist remained often compulsory.

Multiorgan ultrasound based on the RUSH protocol or on the multiorgan ultrasonographic protocol was performed in those cases with haemodynamic instability, shock, unknown hypotension and cardiac arrest.^{5,6} Images

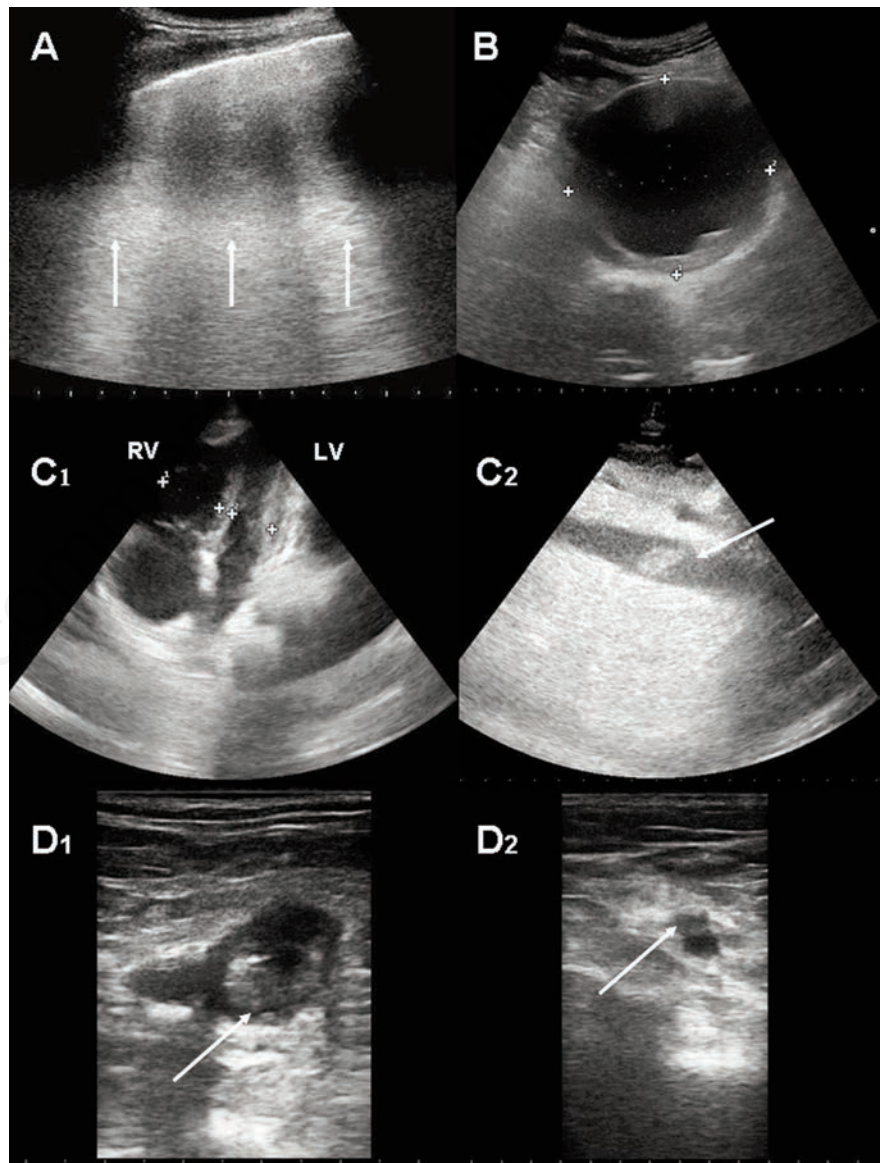


Figure 3. A) B lines in pulmonary oedema (arrows). B) Large abdominal aortic aneurysm. C) A young woman with cardiac arrest and massive pulmonary embolism: acute right ventricle (RV) overload (C1) and a thrombus inside the vena cava (C2, arrow). D) deep venous thrombosis: hyperchoic material and lack of compressibility of femoral (D1, arrow) and popliteal vein (D2, arrow). LV, left ventricle.

obtained from different organs were integrated with clinical symptoms and physiopathology (Figure 3).

It is a new and interesting evolution of CCUS since a rapid and accurate diagnosis is important especially in patients with symptoms that could be manifestations of different pathologies with different or even opposite treatments. Hypotension determined by hypovolemia requires fluid challenge, but fluid challenge can rapidly deteriorate a hypotension secondary to an impaired cardiac function; thrombolysis is indicated when severe hypotension or cardiac arrest are associated with right ventricle overload due to massive pulmonary embolism (Figure 3), but it is contraindicated in hemorrhagic shock; invasive procedures are life saving in cardiac tamponade; immediate surgery is compulsory in patients with shock, abdominal pain and suspected of having a ruptured abdominal aortic aneurysm. A multiorgan approach gives also the chance to monitor treatments and to change therapy according with ultrasonographic findings.^{20,21}

Finally, a small number of invasive procedures were performed. Multiple studies have confirmed that ultrasound improves success and decreases complications in central and peripheral vascular access, thoracentesis, paracentesis, arthrocentesis, regional anesthesia, incision and drainage of abscesses, localization and removal of foreign bodies, lumbar puncture, biopsies, and other procedures.²² In 2012 international evidence-based recommendations on ultrasound-guided vascular access were published and according with them ultrasound guidance has to be suggested as the method of choice for any kind of vascular cannulation given its higher safety and efficacy.²³

Our study has certainly some limitations. First of all ultrasounds were not blinded with respect to primary survey since they were both performed by the same physician, thus influencing the interpretation of ultrasound findings: but, as previously explained we aimed to evaluate the impact of ultrasound in the *real life* of the emergency department where clinical examination and CCUS is always, or nearly always, performed by the same physician. Other limitations were the absence of a control group, the lack of a reliable comparison of diagnostic capability among operators (different medical background, experiences) and the difficulty to calculate the real importance of CCUS in those cases in which ultrasound simply ruled out a specific life-threatening hypothesis.

Despite the above mentioned limitations, we think that our study confirms the importance to integrate primary survey with CCUS. The possibility to obtain a *visual diagnosis* rather than just a clinical hypothesis improved

overall quality of medical assistance together with satisfaction of patients and reduced concern and anxiety of medical operators. Comments of emergency physicians upon the role of CCUS confirmed their appreciation for ultrasound: in the majority of cases CCUS was either crucial for diagnosis or supported/reinforced clinical data.

The small percentages of misleading diagnosis was mainly determined by a wrong interpretation of ultrasonographic images and by the lack of integration of clinical information with ultrasound analysis. Despite the small number of cases we want to focused once more our attention both on the importance to integrate CCUS with primary survey and clinical assessment for a correct interpretation of data and to the collaboration between emergency physicians and consultants to improve the management of our patients.

Conclusions

Although the limitations of the study design, the integration of primary survey with CCUS increased diagnostic capability of the emergency physician and improved rapidity and quality of medical assistance. Point-of-care critical ultrasound must not replace primary survey as well as the referral to a consultant, like echocardiography performed by a cardiologist or diagnostic ultrasonography performed by a radiologist. Collaborations between different specialists are often necessary and advisable, but the emergency physician's proficiency in ultrasound is in a unique position to obtain real-time information and incorporate it with clinical assessments, thus facilitating the management of critically ill patients, preventing possible delays, improving quality and reducing medical costs.

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